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Y o u r   r e s e a r c h   a n d   t e s t   l a b o r a t o r y

**Emissions Measurements in SAEFL EFO Bus Project**  
**Pilot Test of Alternative Filter System from Adastral/Liqtech**  
**with OCTEL (Fe) Additive and ENWA Throttling**

**16 March, 2004**

Dübendorf, May 24, 2004

Project manager:

EMPA Dübendorf  
Air Pollution / Environmental  
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Department head:

K. Zeyer, chem. ing.

Dr. B. Buchmann

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## 1. Introduction and Summary

On 16 March 2004, the Air Pollution / Environmental Technology Laboratory of EMPA performed emissions measurements on LARAG's chassis dynamometer test bench in Wil under contract to TTM Andreas Mayer. The order was placed on 4 February 2004, based on the quotation of 6 January 2004. The measurements constitute part of the SAEFL EFO bus project "Pilot Test of Alternative Filter System from Adastral/Liqtech with OCTEL (Fe) Additive and ENWA Throttling". This report contains the measurements of exhaust gas composition. General information as well as further interpretations are documented in a report by TTM Andreas Mayer for SAEFL.

Two reduced ESC cycles with 9 steady-state modes each were run for the exhaust gas measurements. The samples were taken downstream of the filter system during the first cycle and upstream of the filter system during the second cycle. Special consideration was given to the determination of nitrogen monoxide (NO) and nitrogen dioxide (NO<sub>2</sub>). Sampling was undiluted using a heated filter and Teflon tubing. The samples were then treated in the permeation dryer. This eliminates the losses occurring in the frequently used condensation method frequently used. The analysis of NO and NO<sub>2</sub> was performed using a 2-channel chemiluminescence analyser.

The concentration of nitrogen oxides (NO<sub>x</sub>) was in the range of 428 – 1734 ppm upstream of the filter and between 347 and 1445 ppm downstream of the filter. At all conditions investigated, NO<sub>x</sub> concentration downstream was lower than upstream of the filter. The NO<sub>2</sub> fraction was highest at idle (6.7%), and ranged between 1.6% and 3.6% in all other modes. The concentration of N<sub>2</sub>O was always below the detection limit of 5 ppm.

Measurements:

P. Honegger, K. Zeyer

Evaluation and report:

P. Honegger, K. Zeyer, Dr. L. Emmenegger

## 2. Measurement Program

### MEASUREMENT LOCATION AND TEST CYCLE

LARAG AG chassis dynamometer test bench in Will

Two reduced ESC cycles with 9 steady-state modes each were run for the measurements. The samples were taken downstream of the filter system during the first cycle and upstream of the filter system during the second cycle. In each case, part of the exhaust gas flow was extracted and the concentrations measured undiluted after sample pretreatment preparation.

### MEASURED PARAMETERS

- |                      |  |
|----------------------|--|
| Physical parameters: | - Temperature  |
|                      | - Moisture (H <sub>2</sub> O)  |
| Pollutants:          | - Nitrogen oxides (NO <sub>x</sub> , NO, NO <sub>2</sub> , N <sub>2</sub> O) |
|                      | - Carbon monoxide (CO)   |
|                      | - Volatile organic compounds (VOC)   |

### MEASUREMENT AND PRESENTATION

For each mode, a 3-minute average was determined after constant concentrations were reached (approx. 5 min). The results are given in the tables and plots below. The measurement configuration was identical for both measuring points. The X axes of the bar charts each include the mode No., loading condition and speed.

### N<sub>2</sub>O MEASUREMENT

In the N<sub>2</sub>O measurements using Fourier transform infrared (FTIR) spectroscopy, N<sub>2</sub>O concentration upstream and downstream of the installed Adastr/Liqtech filter system was always below the detection threshold of 5 ppm.

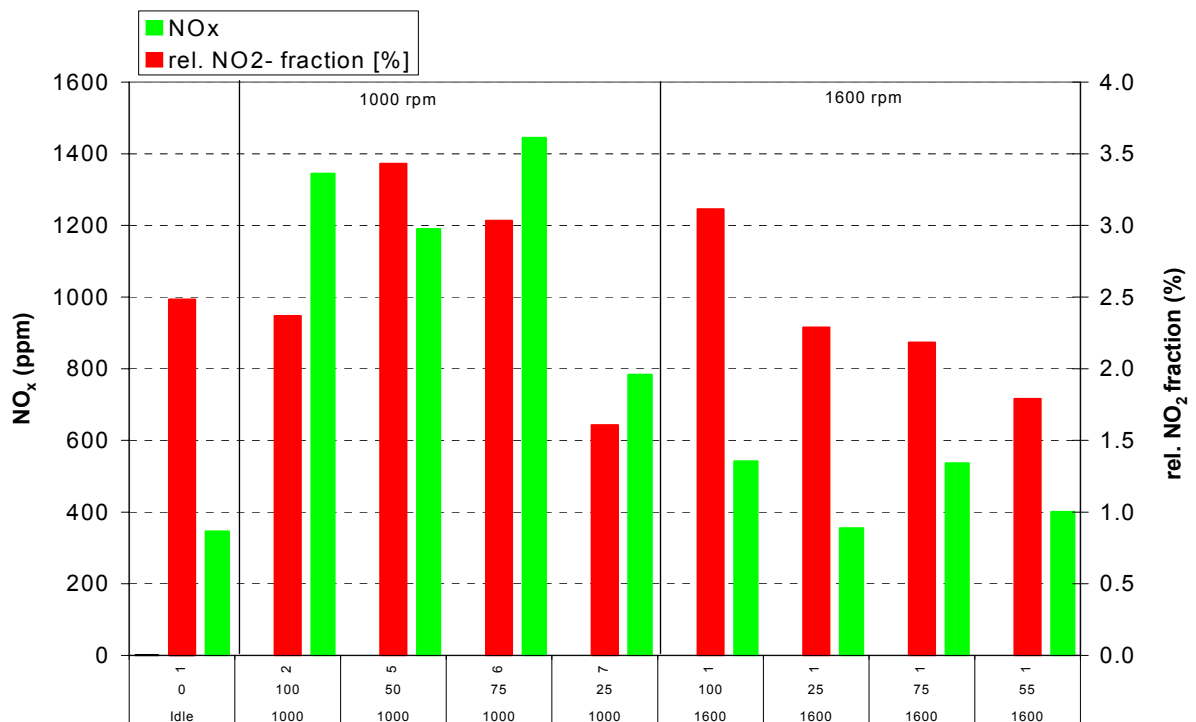
### 3. Results

*Table 1:* Overview of results downstream of filter system

Vehicle: Volvo Euro 3, Model: B12BLE  
Filter: Stobbe DPF, S/N FIL015AL0  
Date: 16 March 2004

Time	Speed	Load	Mode	NO <sub>x</sub>	NO	NO <sub>2</sub>	C <sub>3</sub> H <sub>8</sub>	CO	O <sub>2</sub>	Temp.	NO <sub>2</sub> fraction
	[rpm]			[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[%]	[°C]	[%]
09:51 - 09:56	Idle	0	1	347	338	9	15	49	18	113	2.5
10:03 - 10:08	1000	100	2	1345	1313	32	2	137	6	463	2.4
10:17 - 10:22	1000	50	5	1190	1149	41	3	21	9	399	3.4
10:29 - 10:34	1000	75	6	1445	1401	44	2	71	7	432	3.0
11:03 - 11:08	1000	25	7	784	771	13	5	35	12	317	1.6
11:15 - 11:20	1600	100	10	542	525	17	2	30	9	479	3.1
11:26 - 11:31	1600	25	11	356	347	8	3	26	12	398	2.3
13:45 - 13:50	1600	75	12	537	525	12	5	27	9	438	2.2
13:56 - 14:01	1600	55	13	401	394	7	4	30	10	424	1.8

*Figure 1:* Ratio of nitrogen oxide concentrations downstream of filter

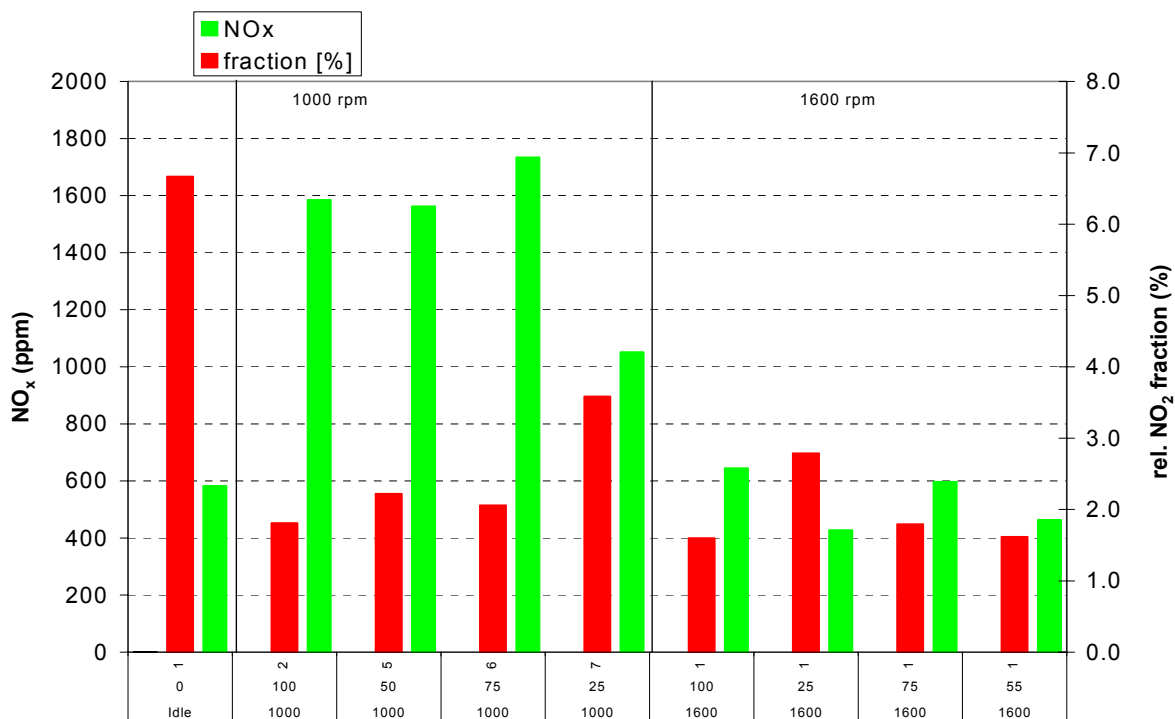


**Table 2:** Overview of results upstream of filter system

Vehicle: Volvo Euro 3, Model: B12BLE  
Filter: Stobbe DPF, S/N FIL015AL0  
Date: 16 March 2004

	Speed	Load	Mode	NO <sub>x</sub>	NO	NO <sub>2</sub>	C <sub>3</sub> H <sub>8</sub>	CO	O <sub>2</sub>	Temp.	NO <sub>2</sub> fraction
	[rpm]			[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[%]	[°C]	[%]
14:45 - 14:48	Idle	0	1	583	544	39	27	3	5	Not measured	6.7
14:55 - 14:58	1000	100	2	1585	1556	29	16	1667	12		1.8
15:03 - 15:06	1000	50	5	1563	1528	35	26	268	10		2.2
15:10 - 15:13	1000	75	6	1734	1699	36	22	749	11		2.1
15:18 - 15:21	1000	25	7	1052	1014	38	30	114	7		3.6
15:27 - 15:30	1600	100	10	644	634	10	16	124	9		1.6
15:35 - 15:38	1600	25	11	428	416	12	23	97	7		2.8
15:42 - 15:45	1600	75	12	597	586	11	17	103	8		1.8
15:50 - 15:53	1600	55	13	464	456	7	20	31	9		1.6

**Figure 2:** Ratio of nitrogen oxide concentrations upstream of filter



*Table 3:* Comparison of nitrogen oxide concentrations upstream and downstream of filter

Location rel. to filter	Speed [rpm]	Load	Mode	NO <sub>x</sub> [ppm]	NO [ppm]	NO <sub>2</sub> [ppm]	NO <sub>2</sub> fraction [%]
upstream	Idle	0	1	583	544	39	6.7
downstream				347	338	9	2.5
upstream	1000	100	2	1585	1556	29	1.8
downstream				1345	1313	32	2.4
upstream	1000	50	5	1563	1528	35	2.2
downstream				1190	1149	41	3.4
upstream	1000	75	6	1734	1699	36	2.1
downstream				1445	1401	44	3.0
upstream	1000	25	7	1052	1014	38	3.6
downstream				784	771	13	1.6
upstream	1600	100	10	644	634	10	1.6
downstream				542	525	17	3.1
upstream	1600	25	11	428	416	12	2.8
downstream				356	347	8	2.3
upstream	1600	75	12	597	586	11	1.8
downstream				537	525	12	2.2
upstream	1600	55	13	464	456	7	1.6
downstream				401	394	7	1.8

- |   |  |
|---|--|
| – Gas preparation for nonreactive gases           | Heated filter, 120°C, Koneth;<br>Heated Teflon line, 120°C, 5 m, Winkler;<br>Permeation dryer PD-750-48-55,<br>Perma Pure Inc./Koneth;<br>unheated PTFE lines (shorter than 5 m) are used<br>from sample preparation to the equipment  |
| – Oxygen  | Susceptibility measurement, continuous;<br>Servomex 570 A; 0–100% O <sub>2</sub>   |
| – Water content<br>(exhaust gas moisture content) | Dew point measurement, continuous  |
| – Carbon monoxide                                 | Nondispersive infrared absorption, continuous<br>Maihak AG;<br>UNOR 610; 0–100 ppm CO  |
| – Nitrogen oxides                                 | Chemiluminescence, continuous,<br>Eco-Physics CLD 700 EL ht;<br>0-1,000 ppm NO <sub>x</sub> and 0-10,000 ppm NO <sub>x</sub>   |
| – Volatile organic compounds                      | Heated gas filter (see above),<br>heated Teflon line, 180°C, 25 m, Winkler;<br>flame ionization detector (FID), continuous,<br>J.U.M VE 7; 0–100 ppm C <sub>3</sub> H <sub>8</sub>   |
| – N <sub>2</sub> O                                | Heated gas filter (see above),<br>heated Teflon line, 180°C, 5 m Winkler<br>heated diaphragm pump, 180°C KNF<br>Type NO12 ST<br>GASMET FTIR gas analyser, Temet Instruments<br>Detector: MCT detector (Peltier cooling)<br>Range: 800-4250 cm <sup>-1</sup><br>Resolution: 16 cm <sup>-1</sup><br>Scans: 10 Scans/s<br>Opt. path length: 980 cm<br>Spectrum averaging: 5 s |

## Uncertainty

The measurement uncertainties given are the 95% confidence limits based on the complete measuring technique, i.e. sampling, sample processing and analysis.

*Table 1: Measurement uncertainties and detection limits*

Parameters	Measurement uncertainties for single values		Detection limit	
—				
Physical parameters				
Air pressure	10	mbar		
Exhaust gas temperature				
- < 100 °C	3	°C		
- 100 – 300 °C	3	%		
Reference parameters				
Oxygen	7	%		
Water	10	%		
Pollutants				
Carbon monoxide	10%	minimum 5 ppm	2	ppm
Nitrogen oxides	10%	minimum 2 ppm	2	ppm
Volatile organic compounds	10%	minimum 2 ppm	2	ppm
N <sub>2</sub> O	10%	minimum 5 ppm	5	ppm

## Appendix 2: Information Note

Concerning the use of EMPA reports for advertising purposes as well as the publication of their contents

Under circumstances, EMPA test reports may be employed as an effective advertising means. However, in view of the independence and neutrality of the EMPA, it is required that certain rules be strictly adhered to. This lies in the interest of the client himself, since violations generally damage the image of the EMPA and thus decrease the effectiveness of the advertising. If a client issues a contract with the intention of utilizing the test report for advertising purposes, he is therefore advised to inform the respective EMPA department of this intention at the outset. In this way, he can also avoid unpleasant surprises (for example, the mentioning of fabrication secrets in the text of the report). The following rules must be adhered to:

### 1. Authorization Requirements

The use of EMPA test reports for advertising purposes as well as the publication of their contents in written or other form, including the mere mention of an EMPA test, is permitted only with the express written consent of the EMPA (Article 15, Paragraph 4 of the Government Regulation concerning the Swiss Federal Laboratories for Materials Testing and Research, January 13, 1993, SR 414.165). If the application is denied, the EMPA is not required to give grounds for the denial. As a rule, consents are given only for reports which are not more than two or three years old.

### 2. Completeness of the Submitted Text

Advertising text is to be submitted to the Marketing Staff at EMPA Dübendorf with its complete wording and with all illustrations. As a rule, this is accomplished through submission of the manuscripts and for printed texts, proof-sheets as well.

### 3. Reference to a Test Report

Every reference to an EMPA report must include the number and date of the EMPA report in question (for ex.: "see EMPA Test Report Nr. 423'511 from February 15, 2000").

### 4. Reference to the Tested Properties

Every reference to an EMPA test report for advertising purposes must mention expressly and completely the properties of the product which was tested (for ex.: "tested by the EMPA for heat conduction and flammability rating").

### 5. Completeness of Quotations

Excerpts from an EMPA test report must be given in their complete wording and must include accurate reproduction of any possible illustrations and explanations.

### 6. Truthfulness in Presentation

Comments, excerpts and conclusions may not be inserted into or added to the text in a misleading way. In particular, the reader may not be given the impression that:

- the EMPA has tested a representative number of objects, whereas in reality only one or a small number of objects were tested,
- the EMPA performs a running control of a product (whereas in reality, only a few samples were tested),
- further properties were tested (in reality, not tested), or
- advertising-oriented conclusions were formulated (in reality, formulated by the client).

### 7. Requirement of Openness

In referring to an EMPA test report, the client accepts the responsibility of providing the complete results of the respective report to every interested party in its full wording including all illustrations and possible explanations. At the same time, he releases the EMPA from its requirement of secrecy regarding these results, however not in regard to fabrication and business secrets (for ex. contents or methods of fabrication).

### 8. Time Limitation

The EMPA retains the right to set a time limit (as a rule, two years) on permits for advertising purposes or publications referred to in this information note. Here, likewise, the EMPA is not obliged to give grounds for setting the time limitation.

### 9. Fees

A fee will be set for the issuing of an advertising permit.

### 10. Consequences of Violations

In the case of violations of the regulations set forth in this information note, the EMPA retains the right to taking all further measures including a corrected presentation (provided to the interested parties who were incorrectly informed) as well as legal measures.